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CBBLSRP FY96 Year-End Report

Measurement of High-Frequency Acoustic Scattering From Coastal Sediments

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Introduction

The focus of this work is measurement of monostatic and bistatic scattering from shallow water sediments. One objective is to use the scattering data to clarify mechanisms responsible for scattering. Another is to use the backscatter data to acoustically monitor physical and biological processes that affect the seafloor. During FY96, processing and interpretation of the Key West bistatic data was the major effort. In addition, backscatter model-data comparisons for all three CBBL sites were completed, and the sonar events seen at Eckernfoerde were studied in detail.

Results - FY96

Bistatic Scattering - Key West

Performance of the bistatic scattering experiments from a vessel in a four point moor allowed better control over experimental geometry and collection of a much larger data set, over a larger range of angles, than in previous bistatic scattering experiments. Of particular note is that there is data encompassing bistatic scattering angles from 0 to 180 degrees (forward scattering to backscattering) and that enough data were acquired to allow better estimation of mean bistatic scattering strength as a function of bistatic scattering angle.

The data are compared in Figures 1 and 2 with the model of Jackson 1993. The model inputs used in Figure 1 were obtained from NRL data as explained in Jackson, Williams, Briggs, and Richardson 1996. The figure has four individual panels. In each panel, all the bistatic scattering strengths with associated incident and scattered grazing angles within a specified range (given in the figure) are plotted as a function of bistatic angle (phi). There are two model curves shown in each panel; one calculated using the incident and scattered grazing angles set to the lowest value of the panel and one with them set to the highest value, e.g., in the top left panel one model curve is for (thetai = thetas = 5 degrees) and the other is for (thetai = thetas = 15 degrees). The overall fit to the data is good throughout most of the bistatic angle range from backscattering to forward scattering. However, there are two characteristics of the data/model comparisons that warrant further comment.

Examination of the top right panel (with thetai and thetas between 10 and 20 degrees) indicates a phi region around 50 degrees where the data fall below the model. Examination of the relative surface and volume scattering in this region indicates that both contribute significantly. Figure 2 shows the same data but with the ratio of compressibility to density fluctuations for the volume scattering changed from the -1.31 given in Jackson, Williams, Briggs, and Richardson 1996 to a

value of -0.66. There is better agreement in the phi range near 50 degrees and little effect outside this range.

Examination of the bottom two panels in Figure 1 or 2 indicate that for the higher incident and scattered grazing angles of these figures the data in the phi region from backscattering (180 degrees) to 90 degrees lies above the model. This effect is also seen in the backscattering data for this site. The reason is unknown but one possibility, as noted below, is the need to account for gradients in sound speed and porosity.

Backscattering - All Sites

Figures 3-5 compare the 40 kHz backscattering data from all three sites with various backscattering models. The model inputs were obtained from NRL data as explained in Jackson, Williams, Briggs, and Richardson 1996. These comparisons indicate that roughness scattering was dominant at the Panama City and Key West sites, while volume scattering due to bubbles was dominant at the Eckernfoerde site (Tang et al. 1994). Generally, first-order perturbation theory gave a good fit to the roughness scattering data, although strong gradients in the sound speed and porosity at Key West suggest that a model allowing for such gradients should be used (Ivakin 1994, Moe and Jackson 1994). Although the composite roughness model is generally considered to be a refinement of the perturbation approximation, it resulted in similar or poorer fits.

Eckernfoerde Acoustic Events

As noted in last year's report, short-lag correlation images show impulsive events localized at a few patches within the sonar field of view. The correlation of these events with sea floor pressure suggests that they are due to ebullition of methane, but the possibility that the events are nothing more than scattering by fish is suggested by their approximately diurnal period. To clarify the nature of these events, we have performed processing to locate the events in three-dimensional space. Matched filtering was used to improve range resolution, and interferometry was used to determine scatterer altitude. Figure 6 shows images of events occurring in one particularly active period. Study of images such as this supports the ebullition hypothesis, as the scatterers tend to form plumes extending from the bottom and have dimensions considerably smaller than expected for fish schools.

Significance of Results to CBBL objectives

The results obtained to date address CBBL objectives at two levels. First, the acoustic data have provided a means of monitoring biological and physical processes over relatively large regions and time spans (as compared to point sampling). Interesting acoustic phenomena that are environmentally driven have been observed, notably, extremely rapid acoustic change at the Panama City site and impulsive events at Eckernfoerde Bay. Second, the data have been used to test physical models for acoustic scattering. In particular, models for scattering by interface roughness and by gas bubbles have been found to provide reasonable fits to the data with no free parameters.

Plans for FY97

We plan to test the bistatic model, as applied to Key West sediment, against forward scattering horizontal coherence data. A journal article will be written documenting the Key West data/ model comparisons. Also, long-term correlation results from the CBBL experiments will be examined further and used in fitting the parameters of a sediment reworking model under development.

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D. Chu, K.L Williams, D. Tang, and D.R. Jackson, "High-frequency bistatic scattering by sub-bottom gas bubbles," J. Acoust. Soc. Am. (In press).

D.R. Jackson, K.L. Williams, T.F. Wever, C.T. Friedrichs, and L.D. Wright, "Sonar observation of events in Eckernfoerde Bay," Continental Shelf Res. (Submitted)

Tang, D., Jin, G., Jackson, D.R., and Williams, K., "Analysis of high-frequency bottom and sub-bottom backscattering for two distinct shallow water sites," J. Acoust. Soc. Am. Vol. 96, 2930-2936 (1994).

Accomplishments Over Past 4 Years

Acquired large, high-quality bistatic and monostatic acoustic scattering data sets from well-characterized sites.

Verified bistatic and monostatic scattering models for Panama City and Key West sites.

In collaboration with Tang and colleagues, tested their bubble scattering model and identified multiple scattering effects.

Measured rate of benthic acoustic change at three sites and found time scales varying by two orders of magnitude

Demonstrated that scattering at Panama City site is a surficial process.

Measured spatial and temporal frequency of pressure driven changes in gaseous methane at Eckernfoerde.

Developed strong evidence that acoustic events in Eckernfoerde data are due to methane ebullition.

Publications resulting from this work

Tang, D., Jin, G., Jackson, D.R., and Williams, K. (1994) Analysis of high-frequency bottom and sub-bottom backscattering for two distinct shallow water sites. Journal of the Acoustical Society of America, Vol. 96, 2930-2936.

D.R. Jackson, K.L. Williams, and K.B. Briggs, "High-Frequency Observations of Benthic Spatial and Temporal Variability," Geo-Marine Letters Vol. 16 212-218 (1996).

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D.R. Jackson, K.L. Williams, T.F. Wever, C.T. Friedrichs, and L.D. Wright, "Sonar observation of events in Eckernfoerde Bay," Continental Shelf Res. (Submitted).

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D. R. Jackson, K. L. Williams, "High Frequency sea-bed scattering measurements in shallow water," Proceedings of 3rd European Conference on Underwater Acoustics.

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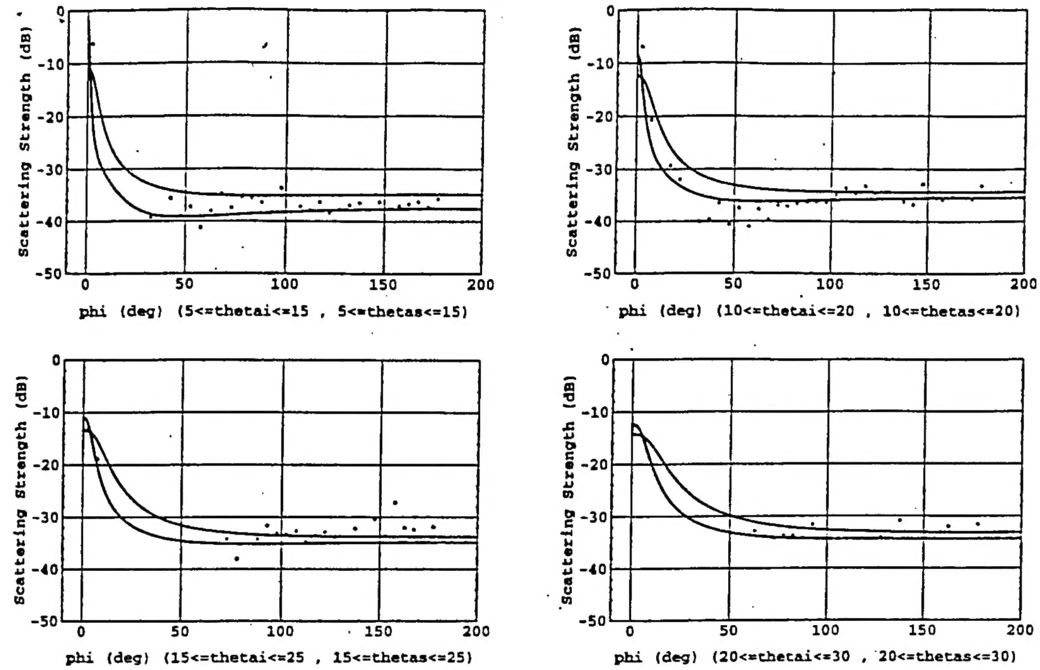

Fig. 1 Bistatic scattering data and model results for Key West. In each panel, all the bistatic scattering strengths with associated incident and scattered grazing angles within a specified range are plotted as a function of bistatic angle (phi). There are two model curves shown in each panel; one calculated using the incident and scattered grazing angles set to the lowest value of the panel and one with them set to the highest value, e.g., in the top left panel one model curve is for (thetai = thetas = 5 degrees) and the other is for (thetai = thetas = 15 degrees).

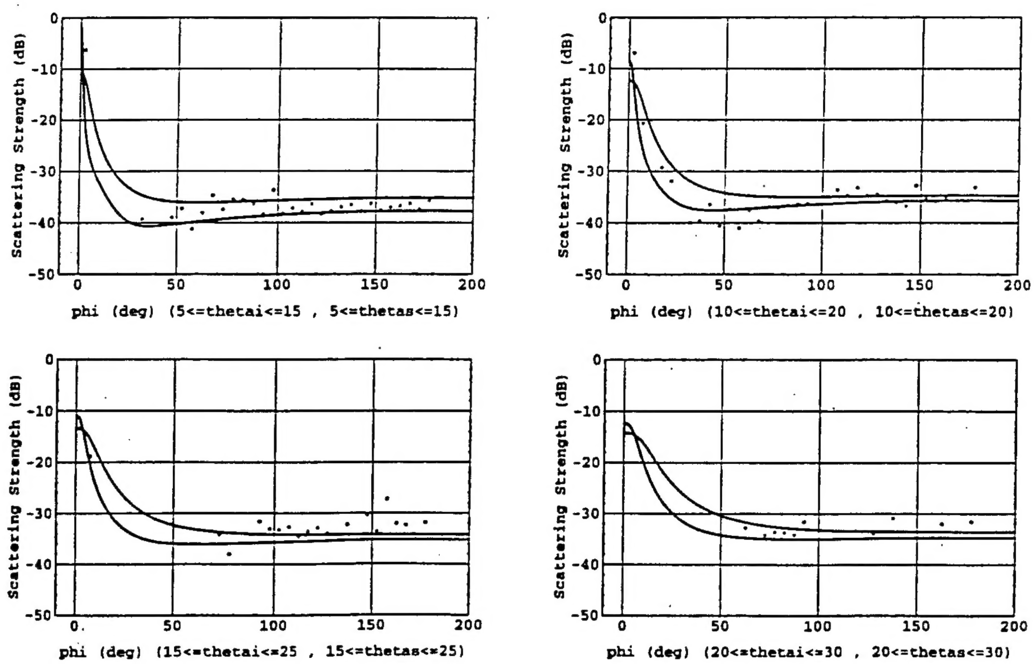

Fig. 2 Same as Figure 1 but with the ratio of compressibility to density fluctuations for the volume scattering changed from the -1.31 given in Jackson, Williams, Briggs, and Richardson 1996 to a value of -0.66. There is better agreement in the phi range near 50 degrees in the top right panel and little effect outside this range.

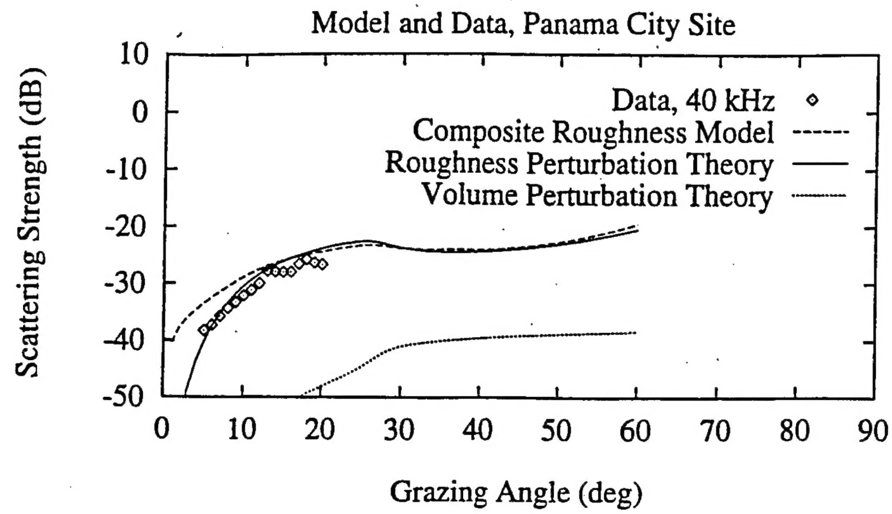

Fig. 3 Backscattering strength data and model predictions for the Panama City site.

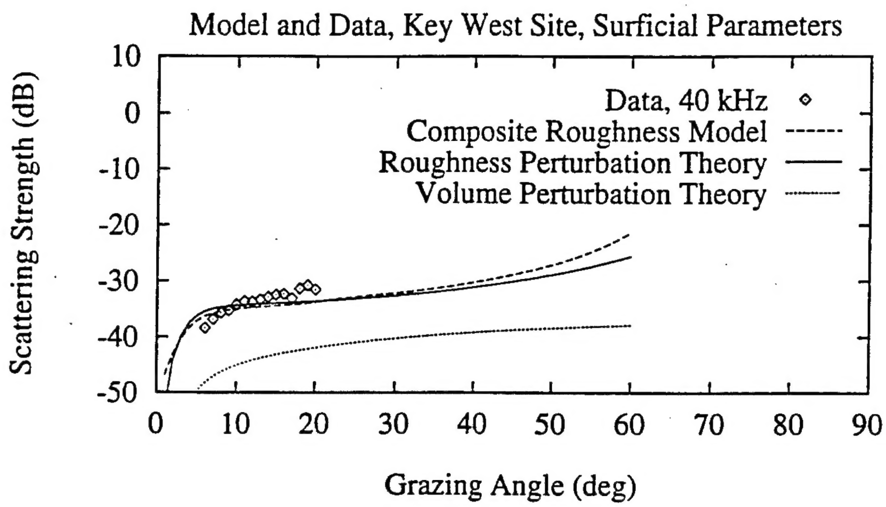

Fig. 4 Backscattering strength data and model predictions for the Key West site using surficial parameters

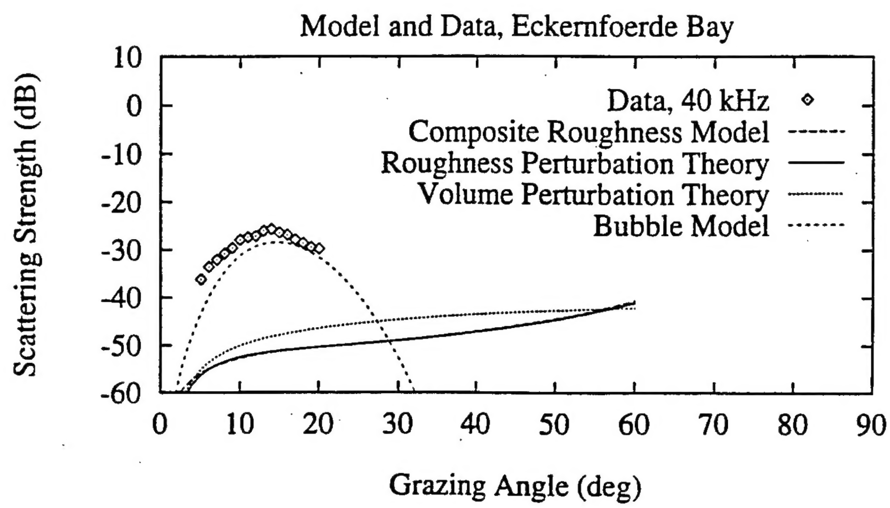

Fig. 5 Backscattering strength data and model predictions for the Eckernfoerde site using parameters averaged over core depth.

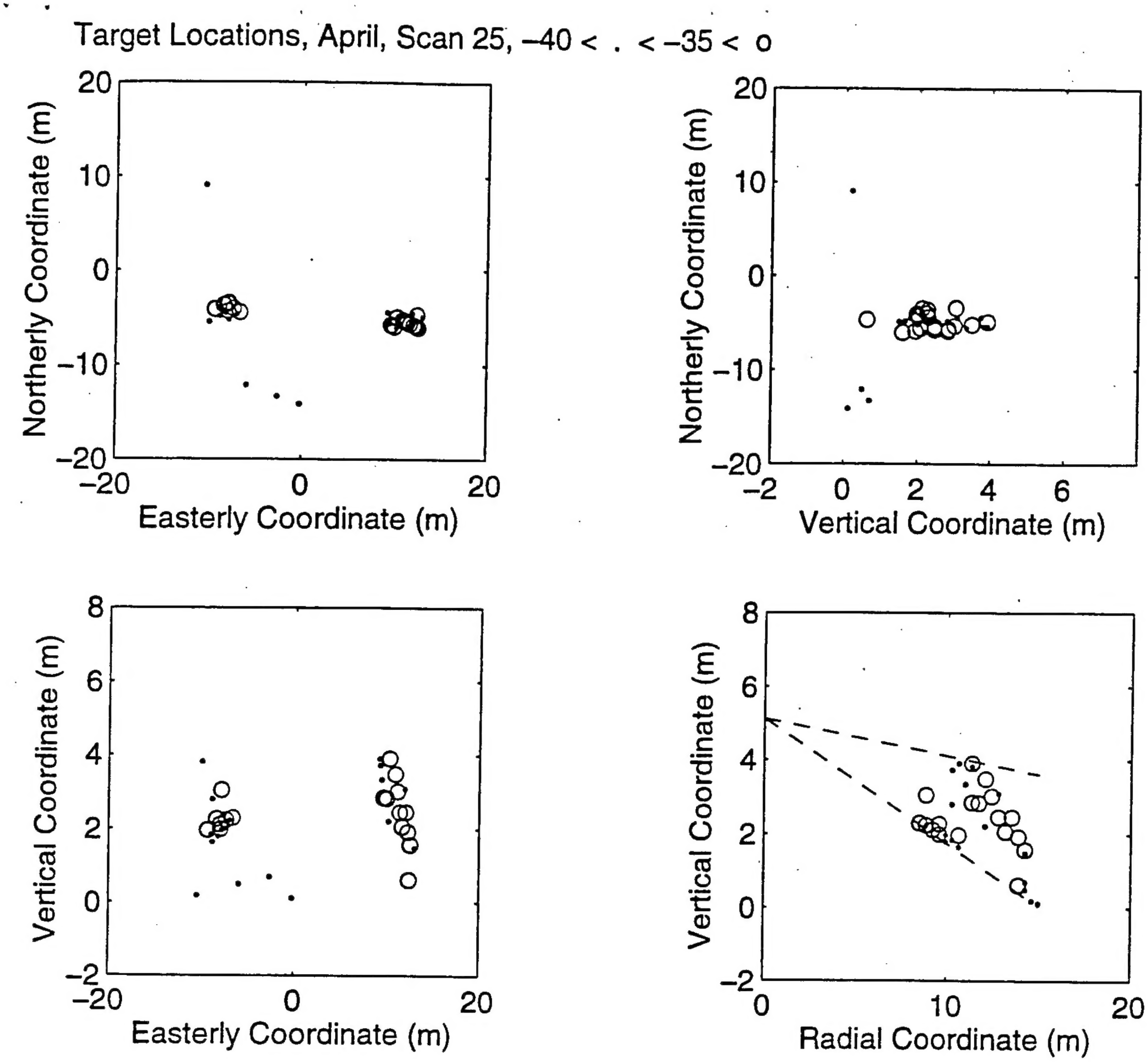

Fig. 6 High resolution images showing targets within 15 m of the sonar transducer. Strong targets having strengths greater than -35 dB are shown as open circles. Weaker targets with strengths between -40 and -35 dB are shown as dots. The limits set by the transducer directivity are shown as dashed lines.

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13. ABSTRACT *(Maximum 200 words)*

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